DEVELOPMENT OF THE STAND BY INUNDATION MODEL FOR NANTUCKET ISLAND, MA

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February, 2009

Contents

List of Tables

List of Figures

Development of a Standby Inundation Model for Nantucket Island, MA

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Abstract

A set of RIM and SIM have been developed for Nantucket Island, MA, an island surrounded by a somewhat irregular continental shelf. Irregular in the sense of the irregular shape of the 100-meter isobath, presenting relatively deep water (200 m or more) to the south, east, and northeast of the island. Due to the wide, and shallow shelf, fronting the study site, in the development of the SIM it was necessary to optimize the grids not by requiring 4 hours of simulation in CPU times of 10 minutes, or less, but 12 hours of simulation in CPU times of 30 minutes, or less. This is due to the fact that it takes more than 4 hours of simulation in order to have the first wave crest reach the selected Warning Point (which coincided with a NOAA tide gauge inside Nantucket Harbor. Having 12 hours of simulation run in 30 minutes, or less, is equivalent to running 4 hours of simulation in 10 minutes, or less. But this longer simulation time allows for several waves to reach the Warning Point.

The Warning Point is well sheltered, lying inside Nantucket Harbor, which opens to the north along the north coast of the island. Henceforth, in no way will the wave heights measured at the Warning Point reflect the waves to be expected along the Atlantic Ocean facing shoreline of the island for sources north of the Caribbean region and at the 1755 Lisbon tsunami source region.

For large events at these two potential source regions it comes out that the island critical facilities, like schools, hospitals, and emergency response facilities seem to lie outside of the danger area.

1.0 Background and Objectives

Figure 1 shows a map of the Atlantic Ocean basin showing the location of Nantucket Island, MA.

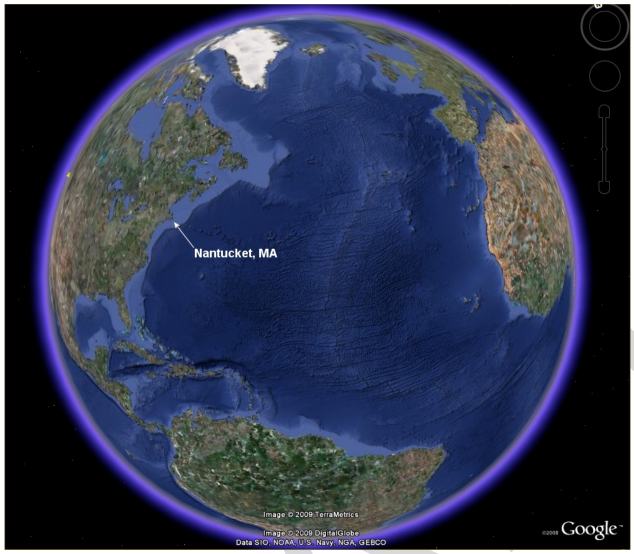

Figure 1 – Map of Atlantic Ocean showing location of study site.

Figure 2 shows a map of the island.

Figure 2 – Map of Nantucket Island.

(The following information was obtained from Wikipedia) **Nantucket** is an island 30 miles (48.3 km) south of Cape Cod, Massachusetts, in the United States. Together with the small islands of Tuckernuck and Muskeget, it constitutes the **town of Nantucket, Massachusetts**, and the coterminous **Nantucket County**, which are consolidated. Part of the town is designated the **Nantucket CDP**, or census designated place. The region of Surfside on Nantucket is the southernmost settlement in Massachusetts.

Nantucket is a tourist destination and summer colony. The population of the island soars from approximately 10,000 to 50,000 during the summer months, due to tourists and summer residents. According to Forbes Magazine, in 2006, Nantucket had the highest median property value of any Massachusetts zip code.

Area (land): 47.8 sq. mi. (123.8 km^2)

Maximum Elevation: 9 m

Population (2007): 10,531

Population Density: 85.1/km^2

Time Zone: Eastern (UTC-5); during the summer it is UTC-4

Transportation

- Nantucket is served by Nantucket Memorial Airport, a three-runway airport on the south side of the island. The airport is one of the busiest in the Commonwealth and often logs more take-offs and landings on a pleasant summer day than Boston's Logan airport. This is due in part to the large number of private/corporate planes used by wealthy summer inhabitants, and in part to the 10-seat Cessna 402s used by several commercial air carriers to serve the island community. The airport is currently undergoing an expansion.
- **Nantucket Regional Transit Authority (NRTA)** - Seasonal Island-wide shuttle services that goes to many destinations including Surfside Beach, Sconset and the Airport.
- Nantucket can be reached by sea from the mainland by using one of three commercial ferry services or by private boat.

Disasters

- The Argo Merchant ran aground on December 15, 1976. A silvery oil slick can be seen coming from the center holds.

Major disasters on or near Nantucket, include:

- On July 25, 1956, 51 people were killed in the collision of the Italian ocean liner SS *Andrea Doria* with the MS *Stockholm* in heavy fog 45 miles (72 km) south of Nantucket.
- On December 15, 1976, the oil tanker *Argo Merchant* ran aground southeast of Nantucket. Six days later, on December 21, the shipwreck broke apart, causing one of the largest oil spills in history.
- On October 31, 1999, Egypt Air Flight 990, traveling from New York City to Cairo, crashed off the coast of Nantucket, killing all 217 on board.

Notice that no mention is made of any observation, or damage, due to the 1929 Grand Banks tsunami. Numerical simulations of this landslide tsunami (Fine et. al., 2005) show that waves (less than 0.5 m) were observed as far south as Atlantic City, MD, and in the island of Bermuda. So one would expect that some wave energy should have reached Nantucket, but apparently it went unnoticed.

A look of the island through Google Earth shows that the island airport is located close to the south shore. The Terrain option of Google Earth shows an elevation of the airport tarmac varying between 4-7 meters above the sea surface on the near shore end, increasing up to 12 meters inland.

The following three figures show the location of schools, fire stations, and hospitals.

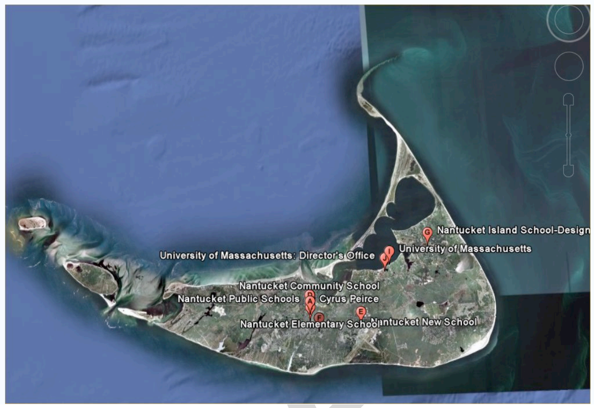

Figure 3 – Location of schools.

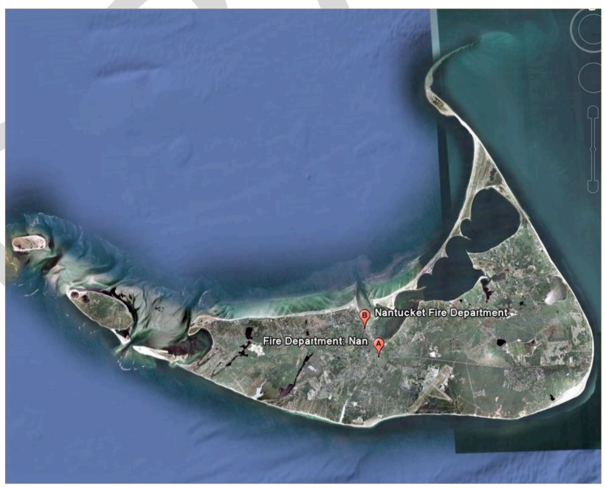

Figure 4 – Location of fire stations.

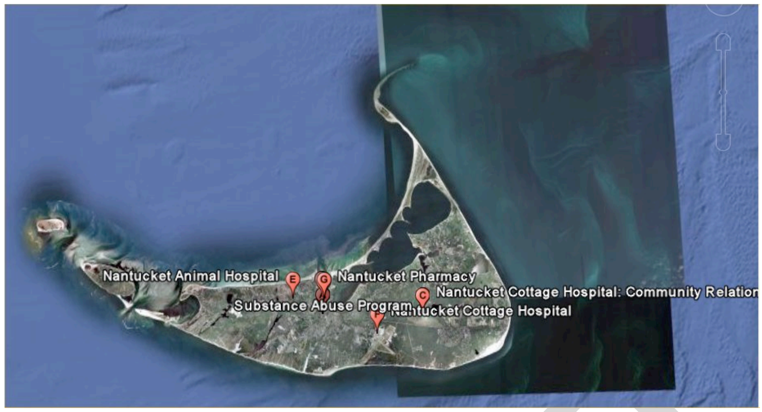

Figure 5 – Location of hospitals.

The DEM with topography/bathymetry were obtained from the Nantucket Island DEM prepared by the NGDC (Taylor et. al., 2008). The

2.0 Forecast Methodology

2.1 Study Area – context

Figures 1 and 2 show the location of the study site and a map of the island of Nantucket. There is a NOAA tide gauge station located at

Table 2.1: Location of NOAA Tide Gauge

Longitude	Latitude
-70.096667	41.285000

Figure 6 shows the location of the gauge, showing it is in a very well protected area. This will be used as the Warning Point (WP).

Figure 6 – Location of tide gauge used as the Warning Point.

(The following information was obtained from Wikipedia) Nantucket was formed by the uttermost reach of the Laurentide Ice Sheet during the recent Wisconsin Glaciation, shaped by the subsequent rise in sea level. The island's low ridge across the northern section was deposited as glacial moraine during a period of glacial standstill, a period during which till continued to arrive, but melted at a stationary front. The southern part of the island is an outwash plain, sloping away from the arc of moraine and shaped at its margins by the sorting actions and transport of longshore drift. Nantucket became an island when rising sea levels reflooded Buzzards Bay about 5000-6000 years ago.

According to the U.S. Census Bureau, Nantucket County has a total area of 303.5 sq mi (786 km²), 84.25% of which is water. The area of Nantucket Island proper is 47.8 sq mi(123.8 km²). The triangular region of ocean between Nantucket, Martha's Vineyard and Cape Cod, is Nantucket Sound. The highest point on the island is Folger Hill which stands 109 feet (33 m) above sea level. Altar Rock is a close second at a height of 108 feet (33 m) above sea level.

The entire island, as well as the adjoining islands of Tuckernuck and Muskeget, comprise both the Town of Nantucket and the County of Nantucket. The main settlement, also called Nantucket, is located at the western end of Nantucket Harbor, where it opens into Nantucket Sound. Key localities on the island include Madaket, Surfside, Polpis, Wauwinet, Miacomet and Siasconset (often abbreviated as 'Sconset).

As mentioned in Section 1.0, there seems to be no record of any tsunami ever hitting the island; not even the 1929 Grand Banks tsunami.

Grid A, for both the RIM and SIM, will be based on a 9 sec DEM prepared for the western North Atlantic Ocean, supplied by Dr. Diego Arcas. A 12 sec version of it is shown in Figure 7 below. Figure 8 shows the DEM supplied by NGDC, with 1/3 sec resolution.

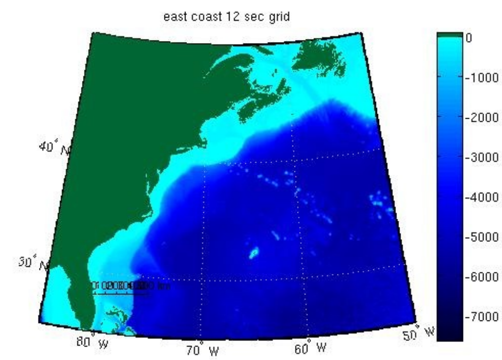

Figure 7 – 12 sec version of western North Atlantic DEM used to prepare Grids A for both RIM and SIM.

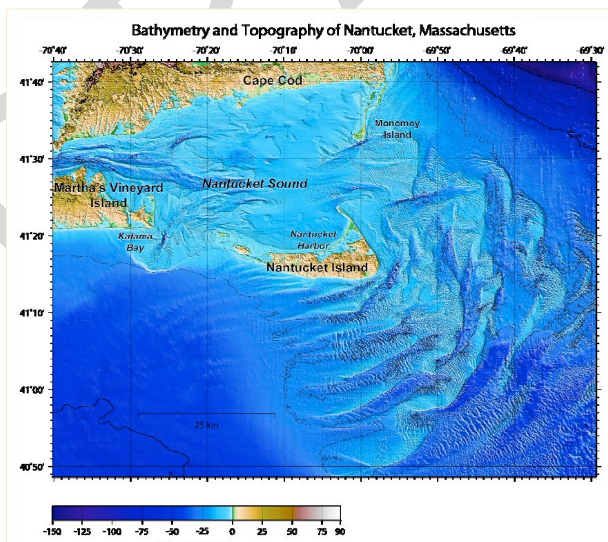

Figure 8 - 1/3 sec Nantucket island DEM from NGDC.

2.2 Model Setup

Reference Grids (RIM):

Figure 9 shows the outline of the 3 RIM grids used. The geographical coverage of reference Grid B is the same as for the DEM.

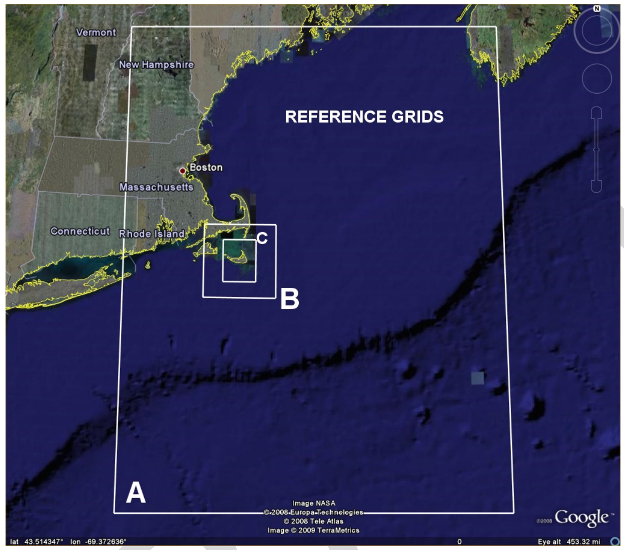

Figure 9 – Google Earth map showing location of the reference grids.

Since there are no recorded historical tsunami data, the reference grids are made with as high resolution as possible in order to create a very reliable sea surface elevation time history for the tsunami events used to test the grids.

Figures 10 to 15 show depth contour plots and surface plots of the RIM grids used. Figures 9 to 11 show the very wide and shallow (that is, depths less than 100 m) continental shelf fronting the study site. The shelf break is about 138 km south of the island. As we will see below, this makes it impossible for the first wave propagating from the two source regions used (the Puerto Rico Trench and the site of the 1755 Lisbon tsunami) to reach the WP in less than 4 hours after the generation of the tsunami.

Due to the problem mentioned above, and following a suggestion from Dr. Diego Arcas, it was decided to do the following. Since the standard goal is to have the 4 hours run in less than 10 minutes of CPU time, then this is equivalent in having 8 hours run in under 20 minutes, and 12 hours in under 30 minutes. And this is how it we proceeded with the work.

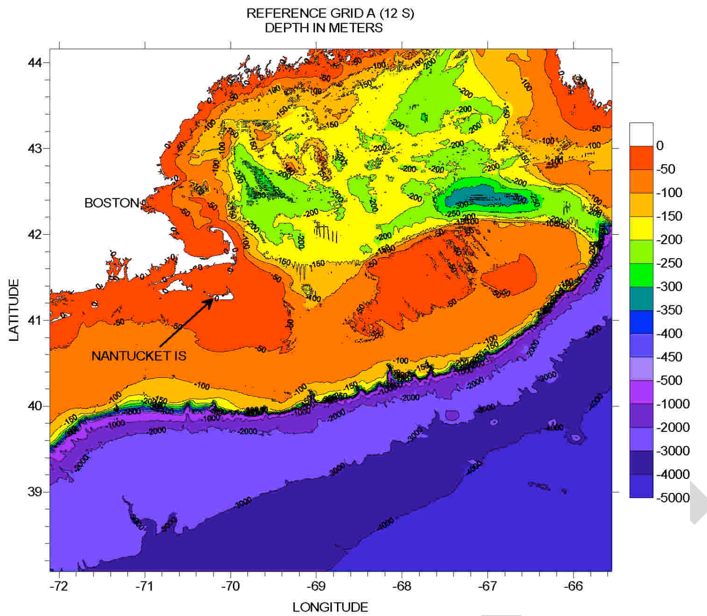

Figure 10 – Depth contour plot of reference grid A.

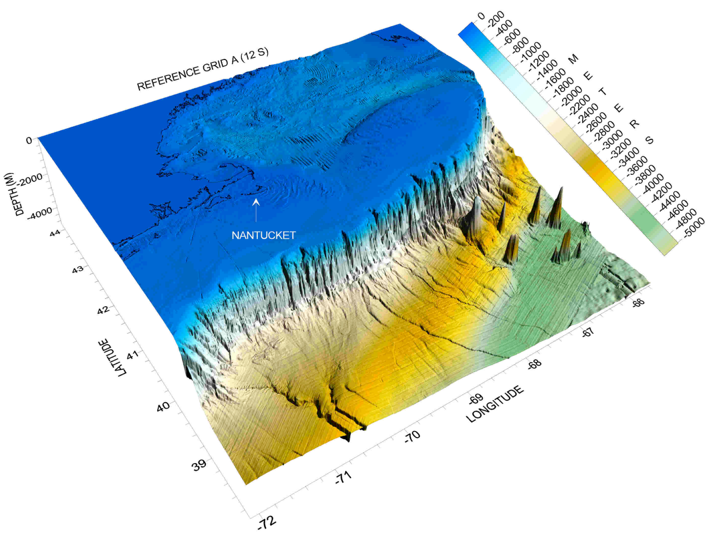

Figure 11 – Surface plot of reference Grid A showing the sharp decrease in water depth seen by the wave as it reaches the continental shelf, and the relatively flat shelf fronting the study site.

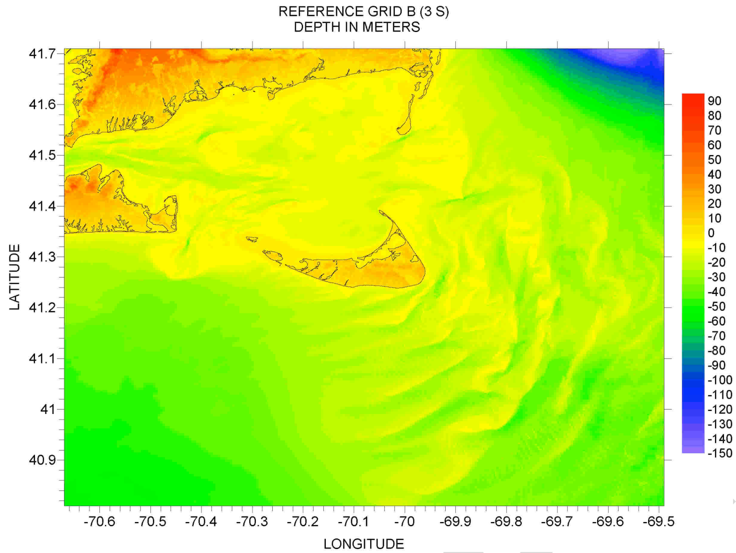

Figure 12 - Depth contour plot of reference grid B. It covers the same geographical area as the DEM.

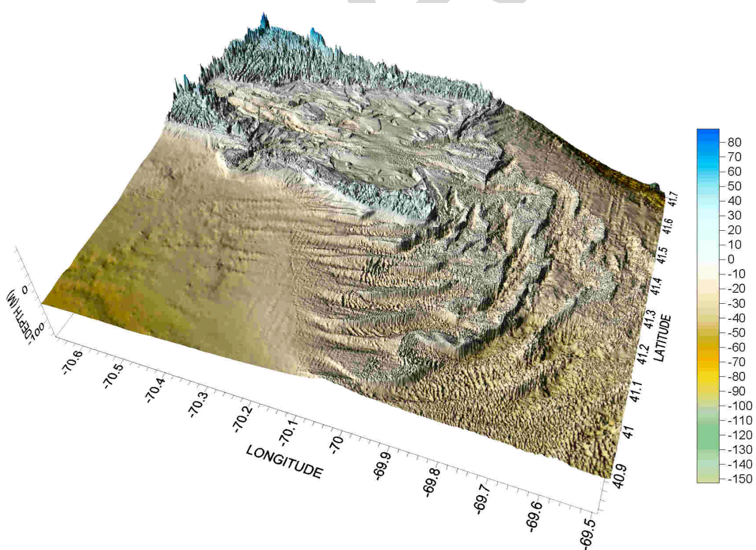

Figure 13 – Surface plot of reference grid B nicely showing the dune-like bedforms fronting the study site.

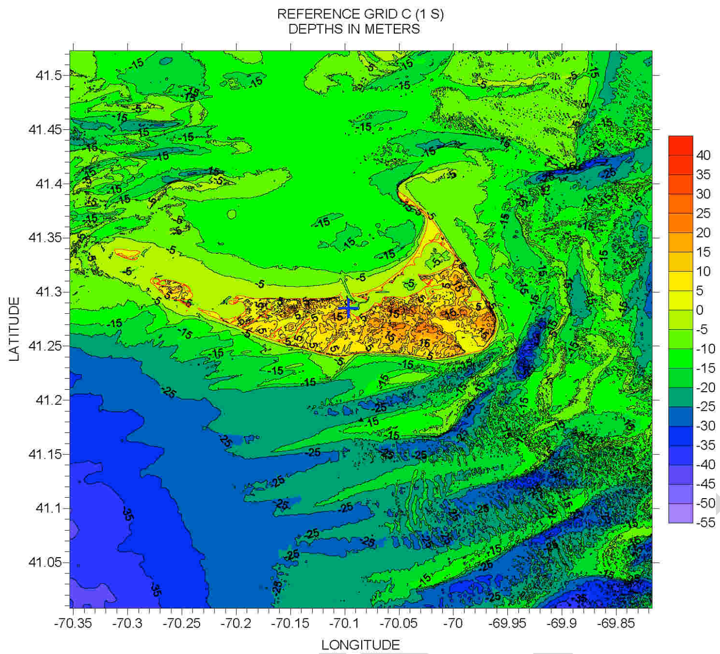

Figure 14 - Depth contour plot of reference grid C.

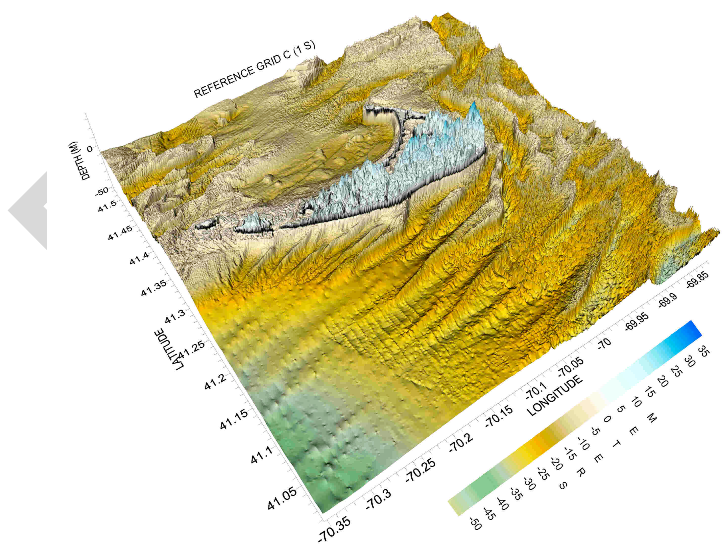

Figure15 - Surface plot of reference grid C nicely showing the dune-like bedforms fronting the study site.

Tables 2-2 to 2-4 show some basic statistics for the three reference grids. The entrance channel to Nantucket Harbor is about 300 meters wide, which has to be considered when searching for an optimized Grid C. For the reference Grid C the grid size is 1 sec, which is about 23 meters, allowing about 13 cells to span the entrance channel at its narrowest.

Table 2-2: Basic Statistics for reference Grid A

Grid File Name:	Grid_A_ref_12s_v1.grd
Grid Size:	1827 rows x 1968 columns
Total Nodes:	3595536
Grid Geometry	
X Minimum:	-72.109693066006
X Maximum:	-65.552870273359
X Spacing:	0.003333412705972 ≈ 285 m
Y Minimum:	38.073769169223
Y Maximum:	44.160638751834
Y Spacing:	0.0033334444592612 ≈ 370 m
Grid Statistics	
Z Minimum:	-5008.869
Z Maximum:	38.9022
Δt_A = 1.318 s	

Table 2-3: Basic Statistics for reference Grid B

Grid File Name:	Grid_B_ref_3s_v1.grd
Grid Size:	1081 rows x 1417 columns
Total Nodes:	1531777
Filled Nodes:	1531777
Blanked Nodes:	0
Grid Geometry	
X Minimum:	-70.6700463
X Maximum:	-69.49004633
X Spacing:	0.00083333331214692 ≈ 71 m
Y Minimum:	40.8099537
Y Maximum:	41.70995368
Y Spacing:	0.00083333331481481 ≈ 92 m
Grid Statistics	
Z Minimum:	-152.58
Z Maximum:	89.2483
Δt_B = 1.795 s	

Table 2-4: Basic Statistics for reference Grid C

Grid File Name:	Grid_C_ref_1s_v1.grd
Grid Size:	1856 rows x 1931 columns
Total Nodes:	3583936
Grid Geometry	
X Minimum:	-70.353101860725
X Maximum:	-69.816990764625
X Spacing:	0.00027777777 ≈ 23 m
Y Minimum:	41.007731475945
Y Maximum:	41.523009239295
Y Spacing:	0.00027777777 ≈ 31 m
Grid Statistics	
Z Minimum:	-52.8201
Z Maximum:	37.4694
Δt_C = 1.022 s	

Optimized Grids (SIM):

Figure 16 shows the outline of the 3 SIM grids finally used. These grids were obtained after testing 17 different combinations of grids. As stated before, the wide and shallow continental shelf made it difficult to obtain the goal of a good match between the reference and optimized elevation time histories and at the same time comply with a CPU time of less than 10 minutes for 4 hours of simulation (recall that in this case this was tested by requiring 20 minutes, or less, for 8 hours of simulation; or 30 minutes for 12 hours of simulation). This was also made worse by the southwest to northeast trend in the shelf break which made it very hard to increase the CFL condition for the optimized Grid A because there was always deep water at the southeast part of the grid.

Figure 16 shows the outline of the RIM and SIM grids inside a depth contour plot of the reference Grid A. Figures 17 to 19 show depth contour plots of the final optimized grids (SIM) used.

Tables 2-5 to 2-7 show basic statistics of the three optimized grids.

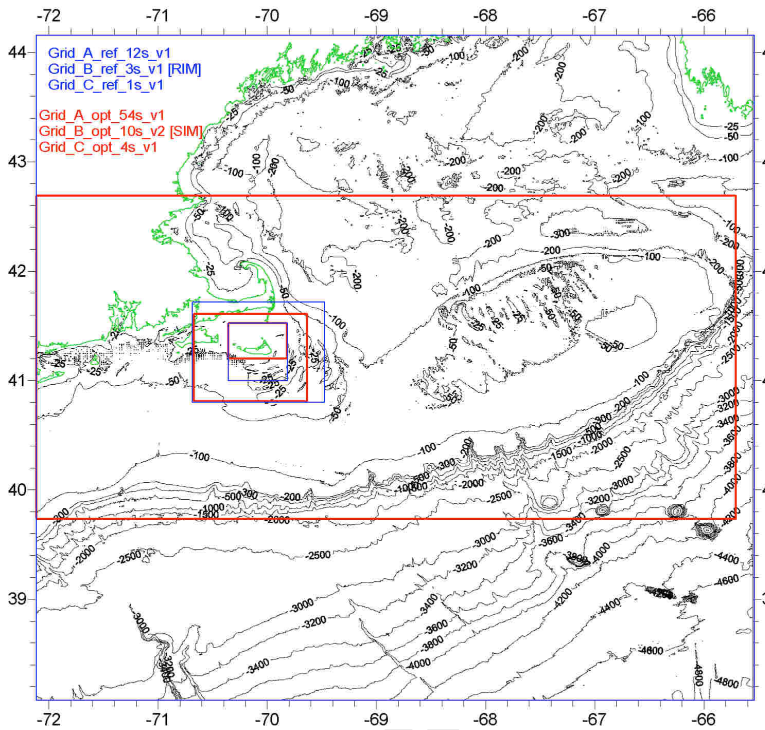

Figure 16 – Outlines of the SIM and RIM grids, shown inside a depth contour plot of the reference Grid A.

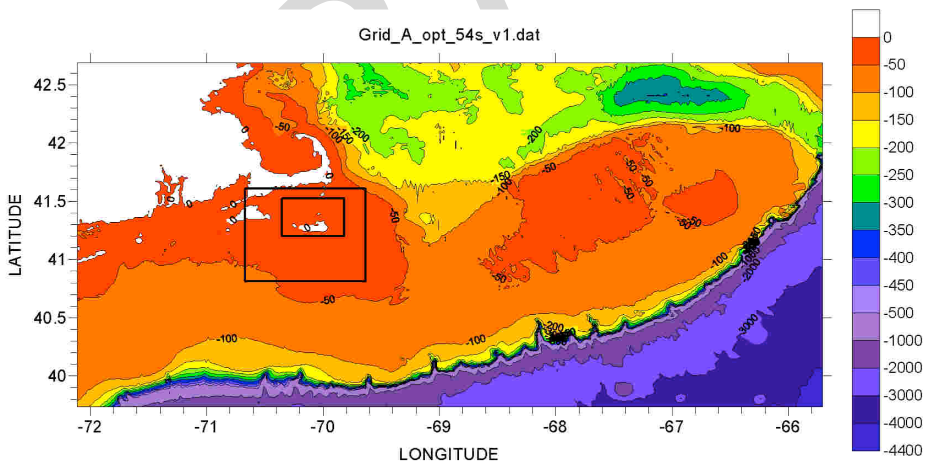

Figure 17 – Depth contour plot of optimized grid A. Also shown is the outline of the optimized grids B and C.

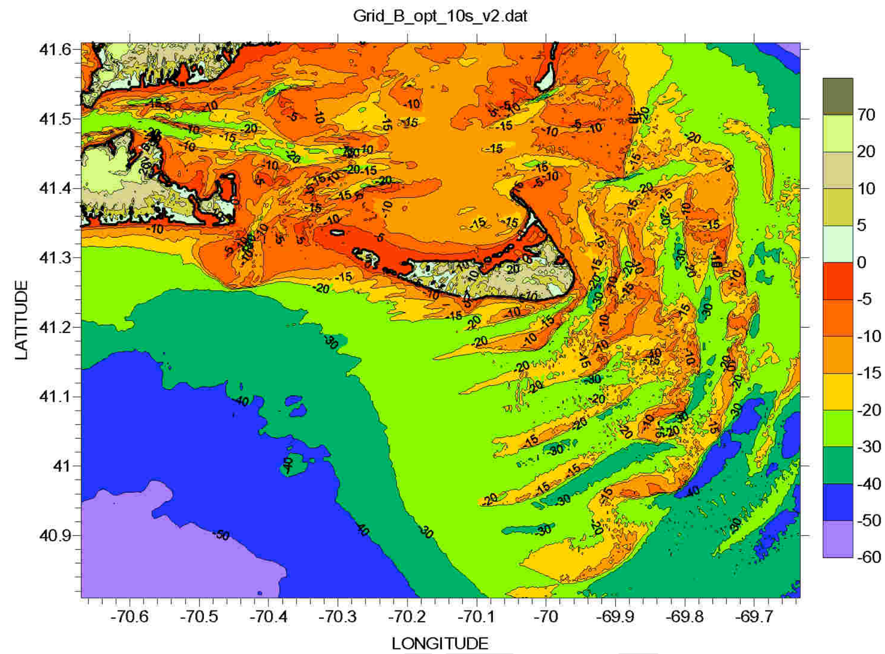

Figure 18 – Depth contour plot of reference grid B.

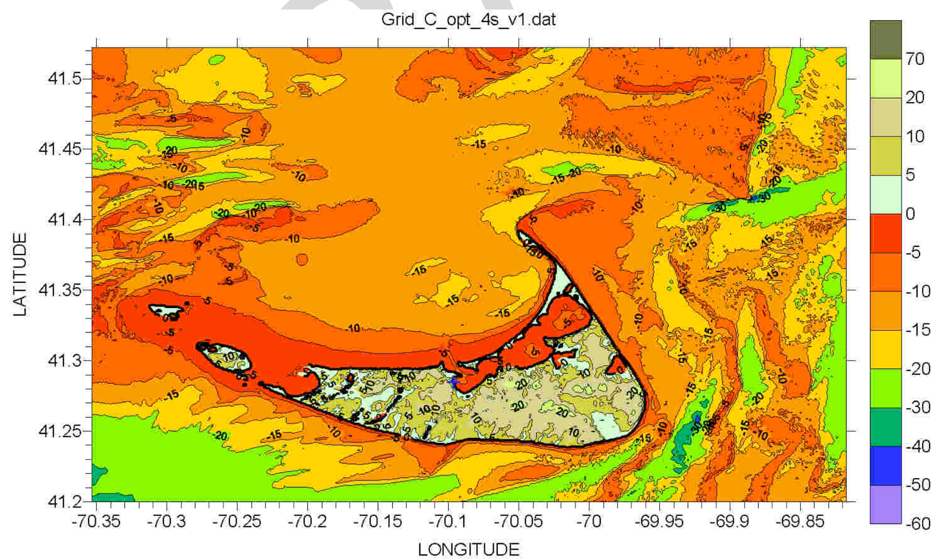

Figure 19 – Depth contour plot of reference grid C. Location of WP is shown by the blue cross.

Table 2-5: Basic statistics of optimized Grid A (Grid_A_opt_54s_v1.dat)

Grid File Name:	Grid_A_opt_54s_v1.grd
Grid Size:	198 rows x 428 columns
Total Nodes:	84744
Grid Geometry	
X Minimum:	-72.114079511359
X Maximum:	-65.708621945992
X Spacing:	0.015001071581656 ≈ 1272 m
Y Minimum:	39.734420768307
Y Maximum:	42.690307623049
Y Spacing:	0.015004501800721 ≈ 1659 m
Grid Statistics	
Z Minimum:	-4251.78
Z Maximum:	10
$\Delta t_A = 6.29$ s	

Table 2-6: Basic statistics of optimized Grid B (Grid_B_opt_10s_v2.dat)

Grid File Name:	Grid_B_opt_10s_v2.grd
Grid Size:	289 rows x 374 columns
Total Nodes:	108086
Grid Geometry	
X Minimum:	-70.6700463
X Maximum:	-69.633935213326
X Spacing:	0.0027777777122627 ≈ 235 m
Y Minimum:	40.8099537
Y Maximum:	41.609953682222
Y Spacing:	0.0027777777160486 ≈ 307 m
Grid Statistics	
Z Minimum:	-59.05
Z Maximum:	67.0822
$\Delta t_B = 9.69$ s	

Table 2-7: Basic statistics of optimized Grid C (Grid_C_opt_4s_v1.dat)

Grid File Name:	Grid_C_opt_4s_v1.grd
Grid Size:	291 rows x 483 columns
Total Nodes:	140553
Grid Geometry	
X Minimum:	-70.353101860725
X Maximum:	-69.817546320165
X Spacing:	0.0011111110800001 ≈ 94 m
Y Minimum:	41.199953692785

Y Maximum:	41.522175905985
Y Spacing:	0.00111111108 ≈ 123 m
Grid Statistics	
Z Minimum:	-49.29
Z Maximum:	34.3667
Δtc = 4.23 s	

Note that the optimized grid spacing of Δx ≈ 94 m implies 3.2 cells spanning the 300 m wide entrance to the Nantucket Harbor.

Historical Events:

There are no recorded historical events at Nantucket Island. But the RIM and SIM can be tested using mega tsunamis whose sources are located at the Puerto Rico Trench and at the source region of the 1755 Lisbon tsunami. Figure 20, from Geist et al.(2005), shows the location of the two potential source regions.

The 1755 Lisbon tsunami is documented in many Internet locations, in O'Loughlin and Lander (2003), and in the NGDC tsunami data base. According to O'Loughlin and Lander it was a Ms ≈ 8.75 to 9.0. There is no recorded history of a tsunami generated at the Puerto Rico Trench, though there was what is considered an 8.0 (Huerfano et al., 2008) earthquake in May 2, 1787.

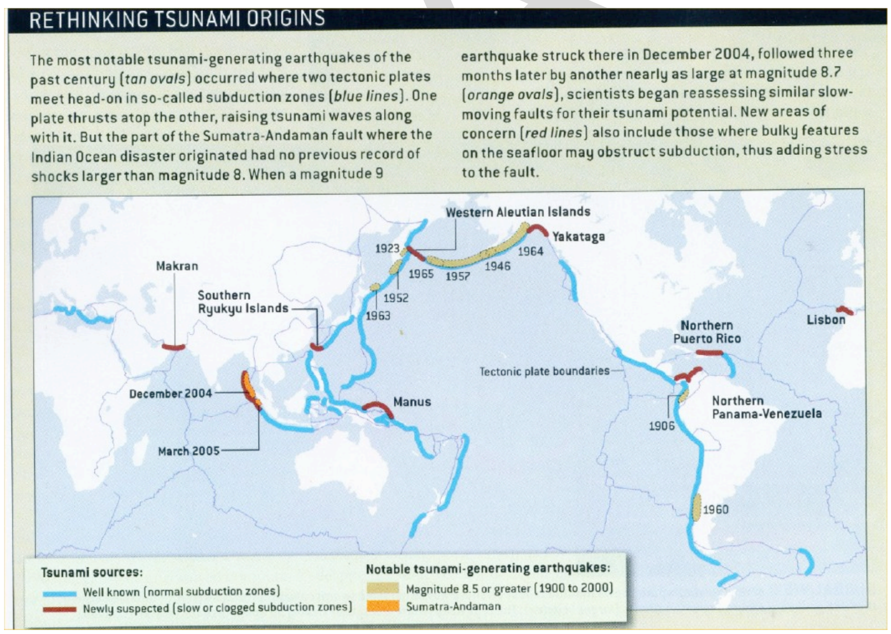

Figure 20 – Potential sources of mega tsunamis, according to Geist et al. (2005).

Therefore, as described below, an Mw 8.9 was synthetically generated at the Puerto Rico Trench using the FACTS page, while an Mw 8.6 was obtained from ComMit for the Lisbon source region.

Artificial Mega Tsunamis:

Puerto Rico Trench:

To obtain the Puerto Rico Trench sources the FACTS WEB page was used, where an 8.9 Mw source was created.

Table 2-8: Puerto Rico Trench (obtained from output *.lis file)

Input FACTS files:
zonal U: /home/amercado/DATA/Atlantic_sources/26565u.nc
meridial V: /home/amercado/DATA/Atlantic_sources/26565v.nc
amplitudes H: /home/amercado/DATA/Atlantic_sources/26565h.nc
length: 118 title:
Atlantic: Mwt 8.9, 11.00*a50+11.00*b50+11.00*a51+11.00*b51+11.00*a52+11.00*b52+11.00*a53+ 11.00*b53+11.00*a54+11.00*b54

Figure 21 shows the rectangles activated for this source.

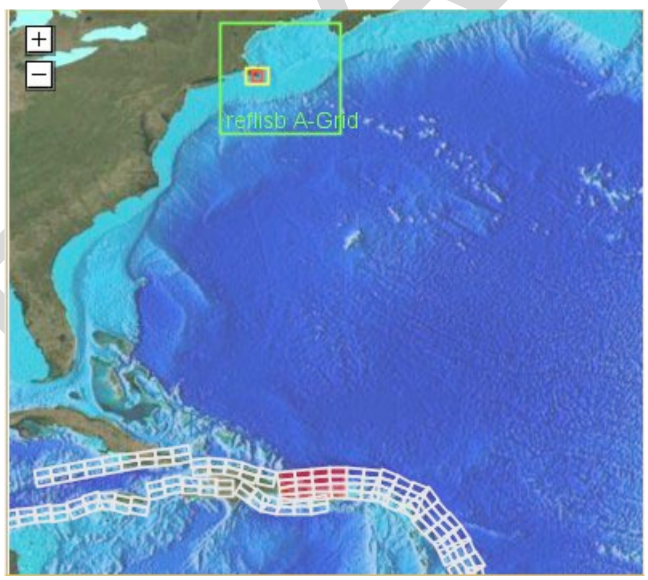

Figure 21 - ComMit map showing the location of the Puerto Rico Trench source area used in this study.

1755 Lisbon Source Area:

For the known potential source area, the region where the 1755 Lisbon tsunami was generated, use was made of ComMit in order to get the source parameters and source files. Figure 22 shows the Lisbon source area relative to Nantucket Island. Four potential sources have been incorporated into the ComMit program, as seen in better detail in Figure 23. Tests were made with each one, and the one producing the highest waves in Nantucket Island was the one named Lisza04 (see Table 2-9), which has the following seismic parameters (see Table 2-10):

Table 2-9: 1755 Lisbon Source Region (obtained from output *.lis file)

```
Input FACTS files:
 zonal U:  /home/amercado/DATA/Atlantic_sources/lisza04u.nc
 meridial V:  /home/amercado/DATA/Atlantic_sources/lisza04v.nc
 amplitudes H:  /home/amercado/DATA/Atlantic_sources/lisza04h.nc
  length:          21  title: MOST Propagation file
```

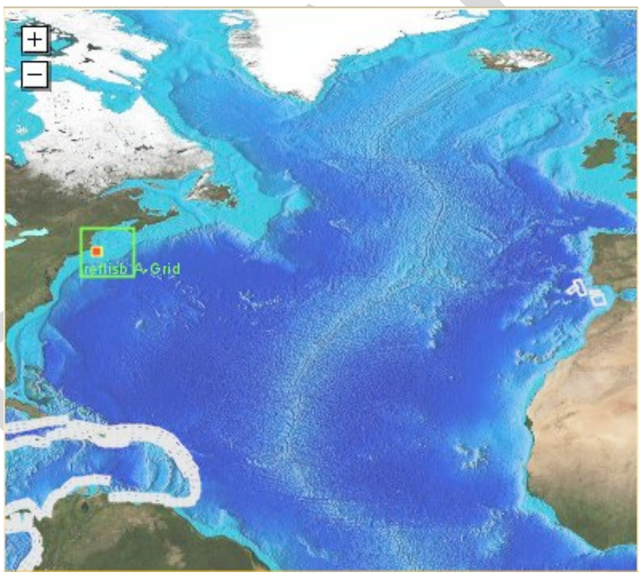

Figure 22 - ComMit map showing the location of 1755 Lisbon tsunami source area used in this study.

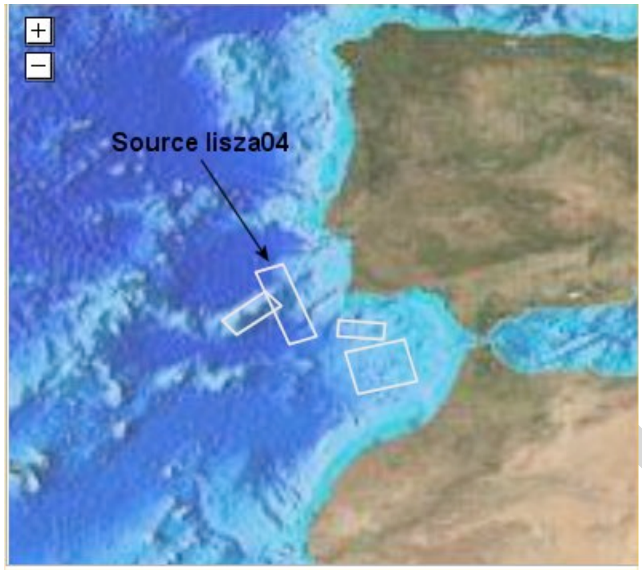

Figure 23 – Figure showing source area for the 1755 Lisbon tsunami. All four sources were tested and the one labeled lisza04 produced the highest waves at the Nantucket Island WP.

Table 2-10: Source Geometry for Lisbon Area Tsunami Lisza04 (obtained from ComMit)

Longitude: -10.0326°
Latitude: 36.9186°
Slip: 13.6 m
Strike: 340.2°
Dip: 45.0°
Depth: 5 km
Length: 210.0 km
Width: 75 km
Rake: 90°
Mw = 8.6

Table 2-11 shows the model setup for both RIM and SIM.

Table 2-11: MOST Model set up parameters for Nantucket Island, MA

Grid	Region	RIM	Cell size (arc s)	Time Step (s)	SIM	Cell Size (arc s)	Time Step (s)
A		Long (°)			Long (°)		
		-72.109693 → -65.552870	12	1.318	-72.114079 → -65.708622	54	6.29
		Lat (°)			Lat (°)		
		38.073769 → 44.160639	12		39.734421 → 42.690308		
B		Long (°)			Long (°)		
		-70.670046 → -69.490046	3	1.795	-70.670046 → -69.633935	10	9.69
		Lat (°)			Lat (°)		
		40.809953 → 41.709954	3		40.809953 → 41.609953		
C		Long (°)			Long (°)		
		-70.353102 → -69.816991	1	1.022	-70.353102 → -69.817546	4	4.23 (used 4.1)
		Lat (°)			Lat (°)		
		41.007731 → 41.523009	1		41.199954 → 41.522176		
Information necessary for SIM: ????????????							
CPU time needed to run		More than 4707 minutes for 4 hours of simulation			Less than 10 minutes for 4 hours of simulation: Puerto Rico Trench: 9.33 min for 4 hours 1755 Lisbon tsunami area: 9.04 min for 4 hours		

3.0 Results

The results shown here were obtained on a workstation running AMD 64-bits 285 2612.054 MHz Opteron processors, running the Portland Group PGI Fortran, and compiled with the switches –O4 –Mipe=fast –tp k8-64. The last one is an Opteron 64-bits specific flag.

3.1 Model Validation

As stated above, there are no recorded tsunami time histories for the study site. Instead, use will be made of simulation results using high resolution grids, and these results will be used as the reference runs with which to compare the results from the optimized grids.

3.2 Model stability and reliability

No stability problems (that is, model blowups or crashes) were encountered. All grids were pre-processed by bathcorr.f with a steepness factor of 0.5. The number of grid points smoothed out by bathcorr.f was always small, on the order of 10 or less, and only one or, at the most, two passes through bathcorr.f were necessary. This is somewhat surprising due to the very pronounced shelf break shown by all grids A. As mentioned above, all grid A were made from a 9 arc sec DEM for the eastern seaboard of the USA. And all grid B's and C's were based on the Nantucket Island DEM obtained from NGDC.

3.3 Results of tested events

The reference grids (RIM) had the following resolution:

Grid A: 12 s (named GridA_ref_12s_v1.dat) See Table 2-2

Grid B: 3 s (named Grid_B_ref_3s_v1.dat) See Table 2-3

Grid C: 1 s (named Grid_C_ref_1s_v1.dat) See Table 2-4

The optimized grids (SIM) had the following resolution:

Grid A: 54 s (named GridA_opt_54s_v1.dat) See Table 2-5

Grid B: 10 s (named Grid_B_opt_10s_v2.dat) See Table 2-6

Grid C: 4 s (named Grid_C_opt_4s_v1.dat) See Table 2-7

All of this is summarized in Table 2-11 above.

Puerto Rico Trench Source

Figures 24 to 26 show the maximum sea surface elevation (in meters) obtained for the Puerto Rico Trench source for the RIM. That is, the maximum elevation obtained at each computational cell irrespective of time. Figures 27 to 29 show the corresponding figures for the SIM.

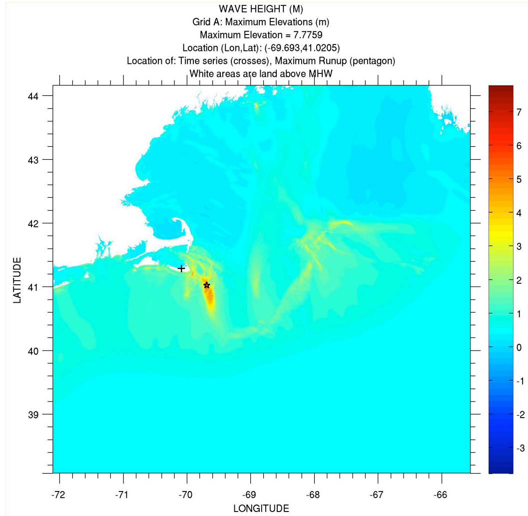

Figure 24 – Sea surface elevation maximum for reference Grid A. Source: Puerto Rico Trench. Simulation time: 12 hrs. Asterisk shows location of maximum value. Black cross marks location of WP.

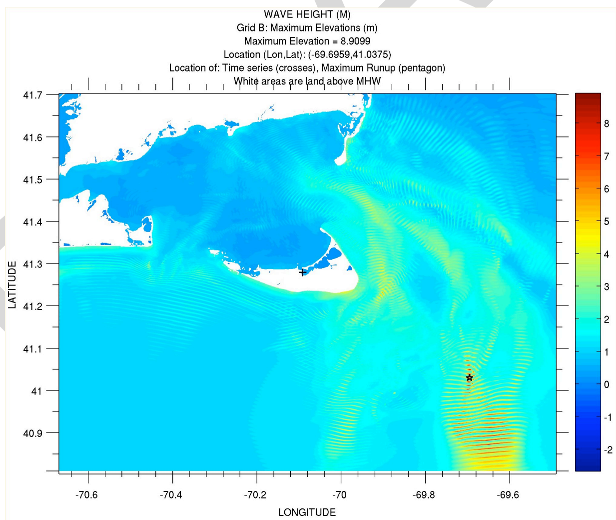

Figure 25 - Sea surface elevation maximum for reference Grid B. Source: Puerto Rico Trench. Simulation time: 12 hrs. Asterisk shows location of maximum value. Black cross marks location of WP.

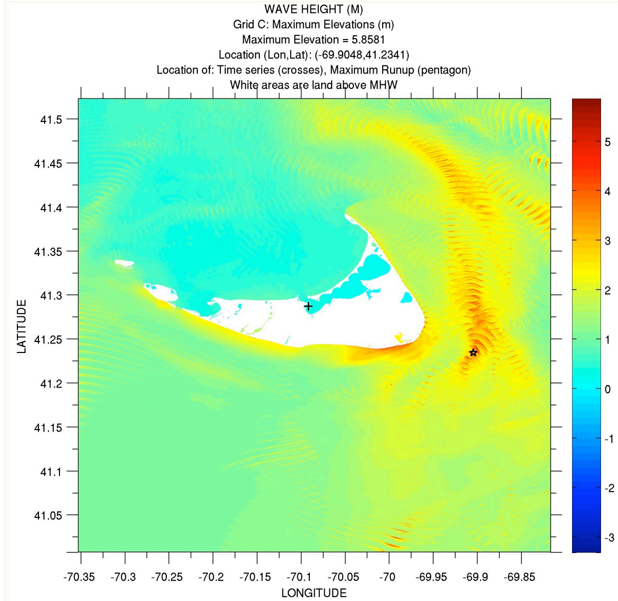

Figure 26 - Sea surface elevation maximum for reference Grid C. Source: Puerto Rico Trench. Simulation time: 12 hrs. Asterisk shows location of maximum value. Black cross marks location of WP.

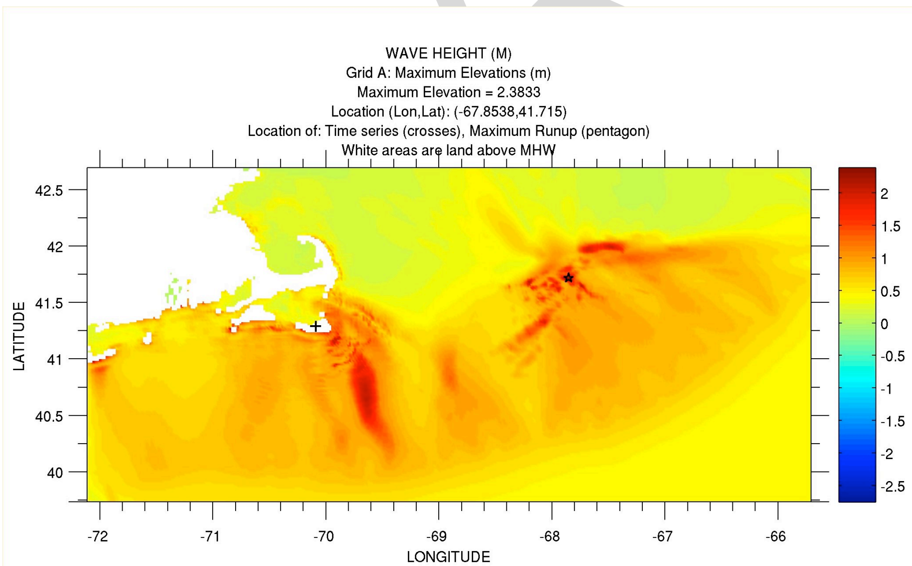

Figure 27 - Sea surface elevation maximum for optimized Grid A. Source: Puerto Rico Trench. Simulation time: 12 hrs. Asterisk shows location of maximum value. Black cross marks location of WP.

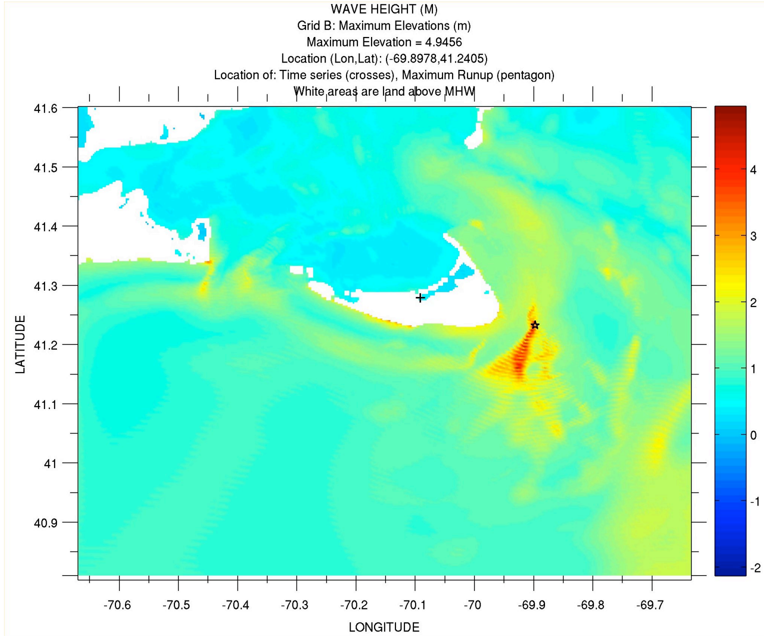

Figure 28 - Sea surface elevation maximum for optimized Grid B. Source: Puerto Rico Trench. Simulation time: 12 hrs. Asterisk shows location of maximum value. Black cross marks location of WP.

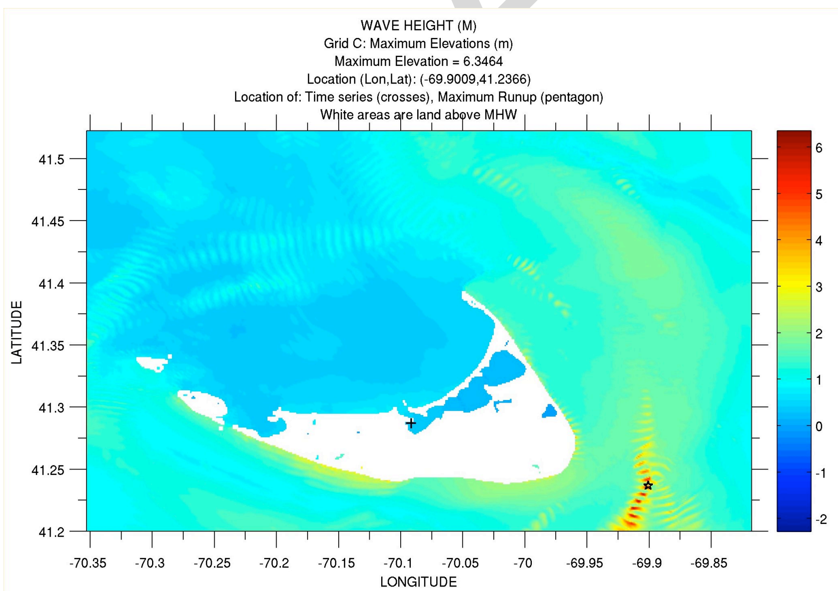

Figure 29 - Sea surface elevation maximum for optimized Grid C. Source: Puerto Rico Trench. Simulation time: 12 hrs. Asterisk shows location of maximum value. Black cross marks location of WP.

Figure 30 shows a comparison of the time series for the RIM and SIM for 12 hours of simulation. The CPU time for the optimized run was 28.01 minutes, which for 4 hours of simulation comes to 28.01/3 = 9.33 minutes. The corresponding *.in and *.lis files are shown in the appendix. In order to obtain the time series, the location of the WP had to be moved as follows:

Table 3-1: Location of NOAA tide gauge versus final location of WP

Original		New	
Longitude	Latitude	Longitude	Latitude
-70.096667	41.285000	-70.0917624662	41.2868897622

Otherwise the location of the WP fell slightly inland on our optimized Grid C.

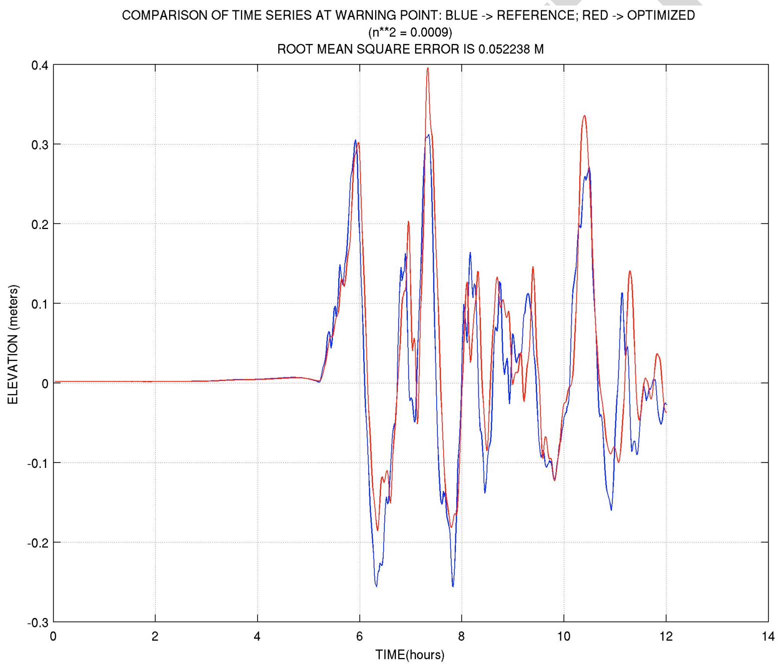

Figure 30 – Time series comparison between the RIM and the SIM. Source: Puerto Rico Trench. The Root Mean Square Error (RMSE) is 0.052 meters. Notice that the signal arrived after 4 hours of simulation had elapsed.

Lisbon 1755 Tsunami Source Region (lisza04)

Figures 31 to 33 show the maximum sea surface elevation (in meters) obtained for the lisza04 source in the 1755 Lisbon tsunami region for the RIM. That is, the maximum elevation obtained at each computational cell irrespective of time. Figures 34 to 36 show the corresponding figures for SIM.

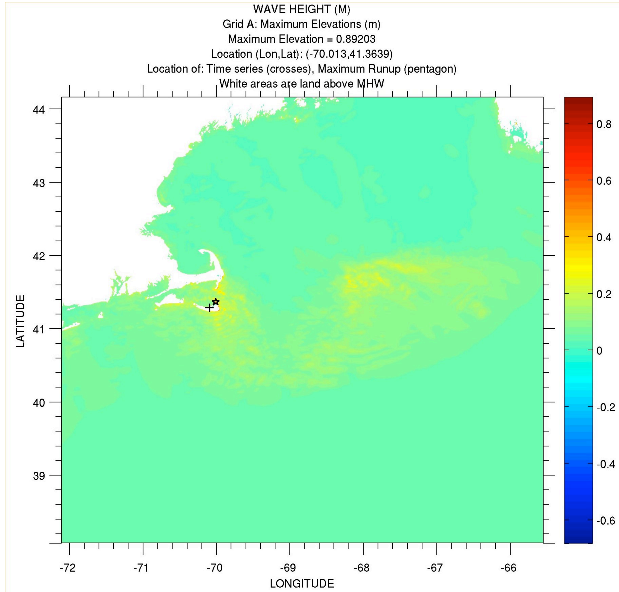

Figure 31 - Sea surface elevation maximum for reference Grid A. Source: lisza04. Simulation time: 12 hrs. Asterisk shows location of maximum value. Black cross marks location of WP.

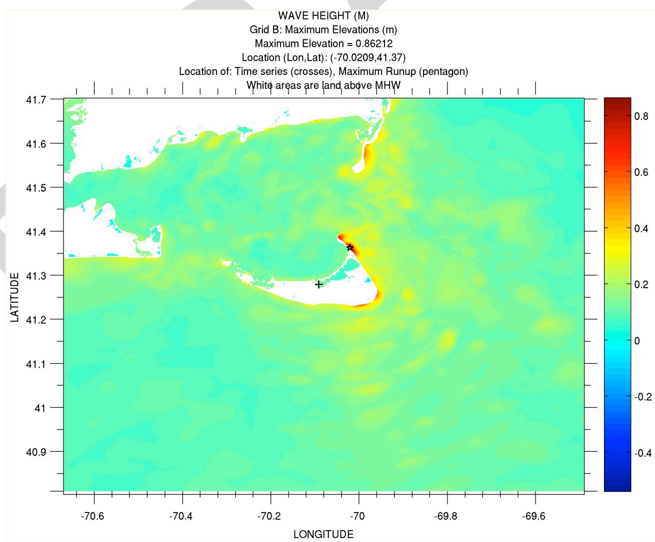

Figure 32 - Sea surface elevation maximum for reference Grid B. Source: lisza04. Simulation time: 12 hrs. Asterisk shows location of maximum value. Black cross marks location of WP.

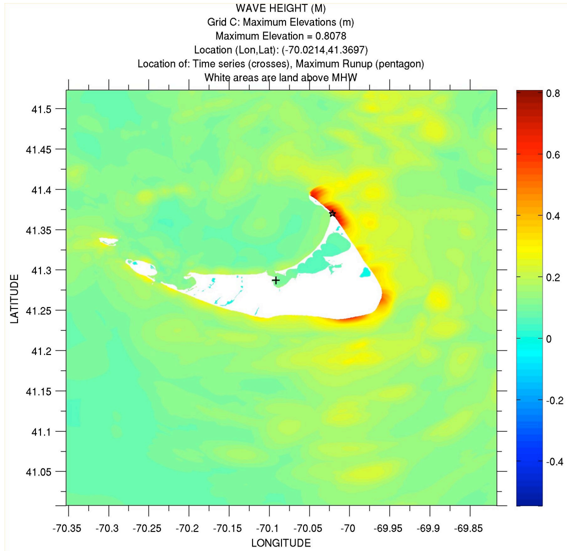

Figure 33 - Sea surface elevation maximum for reference Grid C. Source: lisza04. Simulation time: 12 hrs. Asterisk shows location of maximum value. Black cross marks location of WP.

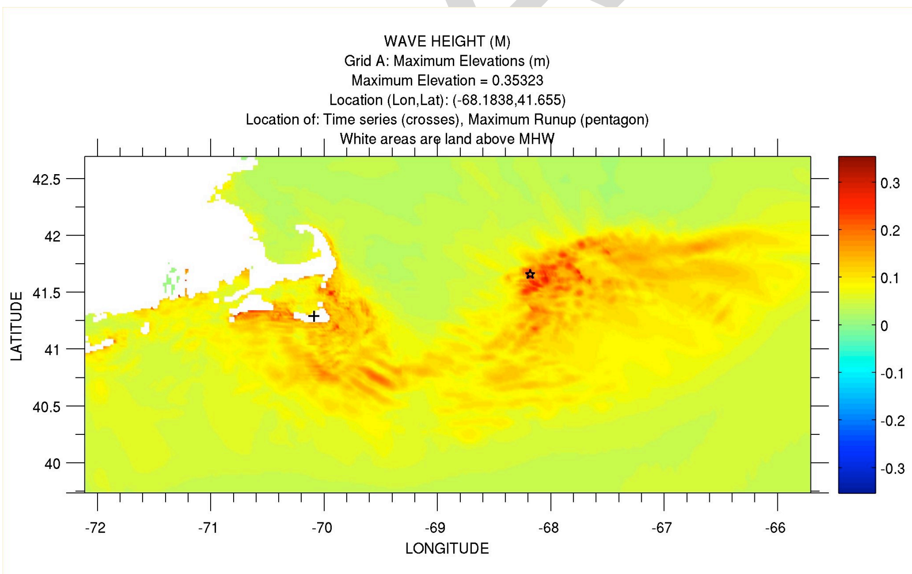

Figure 34 - Sea surface elevation maximum for optimized Grid A. Source: lisza04. Simulation time: 12 hrs. Asterisk shows location of maximum value. Black cross marks location of WP.

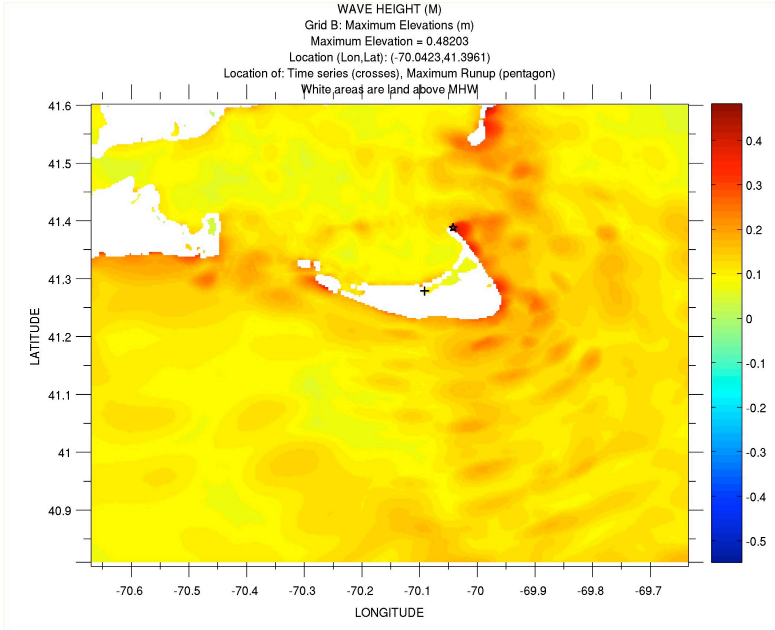

Figure 35 - Sea surface elevation maximum for optimized Grid B. Source: lisza04. Simulation time: 12 hrs. Asterisk shows location of maximum value. Black cross marks location of WP.

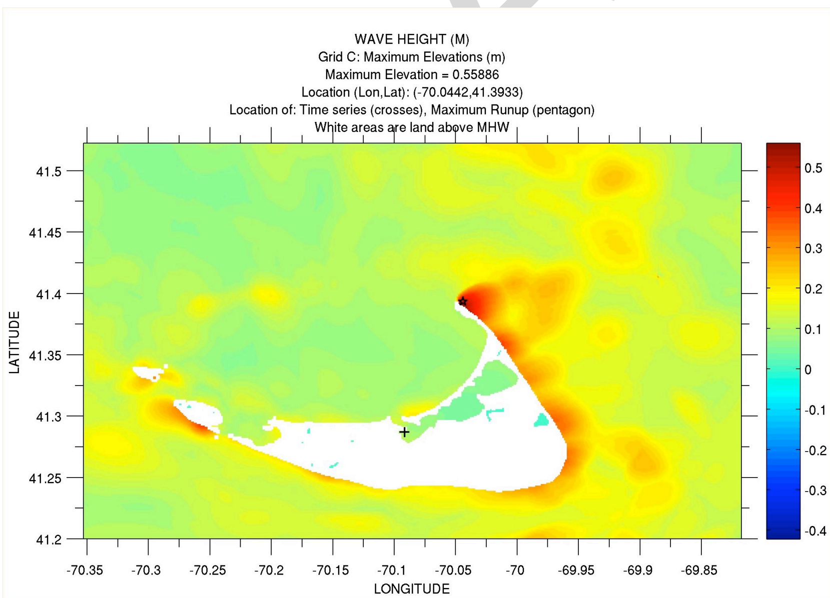

Figure 36 - Sea surface elevation maximum for optimized Grid C. Source: lisza04. Simulation time: 12 hrs. Asterisk shows location of maximum value. Black cross marks location of WP.

Figure 37 shows a comparison of the time series for the RIM and SIM for 12 hours of simulation. The CPU time for the optimized run was 27.12 minutes, which for 4 hours of simulation comes to 27.12/3 = 9.04 minutes. The corresponding *.in and *.lis files are shown in the appendix.

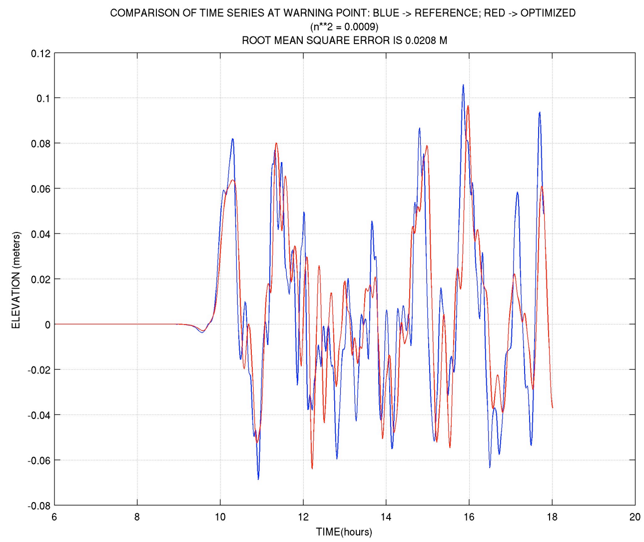

Figure 37 - Time series comparison between the RIM and the SIM. Source: 1755 Lisbon tsunami source region. The Root Mean Square Error (RMSE) is 0.021 meters. Notice that the crest of the first wave arrived after 4 hours of simulation.

All of these results are summarized in Table 2-11 above.

4.0 Discussion

As mentioned above, the wide, and shallow, continental shelf fronting Nantucket Island prevented the wave from reaching the WP within the first four hours of simulation for a source at the Puerto Rico Trench. For a source at the 1755 Lisbon source area the first wave was detected at the end of the third hour of simulation, but the crest of the wave took slightly more time to pass. Hence, what was done was to increase the simulation time to 12 hours, and since 4 hours had to be run in 10 minutes, or less, of CPU time, the 12 hours had to run in less than 30 minutes.

Another problem encountered was the southeast to northeast trending of the shelf break. For Grid A this resulted in always having the southeast corner of the grid to lie in deep water, which did not allow to increase its time step because of the CFL condition. This in turn, forced the use of a grid size in the optimized Grid C larger than what was originally desired.

5.0 Summary and Conclusions

A set of RIM and SIM have been developed for Nantucket Island, MA, an island surrounded by a somewhat irregular continental shelf. Irregular in the sense of the irregular shape of the 100-meter isobath, presenting relatively deep water (200 m or more) to the south, east, and northeast of the island.

The Warning Point, lying inside Nantucket Harbor, which opens to the north, lies in a well-sheltered location. Therefore, the wave heights measured a the WP could be much smaller than what the south and east coast of the island could be exposed during an event from the potential sources lying north of the Caribbean region and at the 1755 Lisbon tsunami source area.

For large events at these two potential source regions it comes out that the island critical facilities, like schools, hospitals, and emergency response facilities seem to lie outside of the danger area.

6.0 Acknowledgments

I would like to acknowledge the support of NOAA's Center for Tsunami Research, and especially of Dr. Diego Arcas.

7.0 References

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8.0 Appendix

Input *.in file for reference runs.

```
0.001    Minimum amplitude of input offshore wave (m):
1        Input minimum depth for offshore (m)
0.1      Input "dry land" depth for inundation (m)
0.0009   Input friction coefficient (n**2)
1        let a and b run up
30.0     max eta before blow up (m)
0.92     Input time step (sec)
46956    Input amount of steps (12 hrs)
1        Compute "A" arrays every n-th time step, n=
1        Compute "B" arrays every n-th time step, n=
60       Input number of steps between snapshots (60 s)
0        ...Starting from
1        ...Saving grid every n-th node, n=
Grid_A_ref_12s_v1.dat
Grid_B_ref_3s_v1.dat
Grid_C_ref_1s_v1.dat
/home/amercado/DATA/Atlantic_sources/
/home2/amercado/DATA/N2/MOST_runs_1/MOST_output_1/
```

Input *.in file for optimized runs.

```
0.001    Minimum amplitude of input offshore wave (m):
1        Input minimum depth for offshore (m)
0.1      Input "dry land" depth for inundation (m)
0.0009   Input friction coefficient (n**2)
1        let a and b run up
100.0    max eta before blow up (m)
4.1      Input time step (sec)
10536    Input amount of steps (12 hrs)
1        Compute "A" arrays every n-th time step, n=
2        Compute "B" arrays every n-th time step, n=
14       Input number of steps between snapshots (57.4 s)
0        ...Starting from
1        ...Saving grid every n-th node, n=
Grid_A_opt_54s_v1.dat
Grid_B_opt_10s_v2.dat
Grid_C_opt_4s_v1.dat
/home/amercado/DATA/Atlantic_sources/
/home/amercado/DATA/N1/MOST_runs_1/MOST_output_1/
```